



Evaluation Criteria in the Generation IV Technology Roadmap

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Outline

- 1. Roadmap project overview***
- 2. Evaluation methodology approach***
- 3. Criteria and metrics***
- 4. Observations on methodology***

The Generation IV Technology Roadmap

Objectives:

- ***Describes systems deployable by 2030 or earlier***
- ***Determines which systems offer significant advances towards:***
 - ***Sustainability***
 - ***Safety and reliability***
 - ***Economics***
- ***Examines R&D pathways for nuclear technology***
- ***Plans for a Generation IV R&D program***

Key Steps for the Roadmap

- **Define Technology Goals for Generation IV**
 - **Technology Goals Document** **March 2001**
- **Identify Concepts with Potential**
 - **Broad Request for Information** **April 2001**
- **Evaluate Concepts with a Common Methodology**
 - **Qualitative Screening for Potential** **Sep 2001**
 - **Quantitative Final Screening** **Mar 2002**
 - **Selection of concepts** **(underway)**
- **Identify R&D Gaps and Needs** **(underway)**
- **Assemble a Program Plan**
 - **Integration and writing:** **Summer 2002**

Eight Goals within Three Goal Areas

Sustainability

Resource inputs

SU-1: Generation IV nuclear energy systems including fuel cycles will provide sustainable energy generation that meets clean air objectives and promotes long-term availability of systems and effective fuel utilization for worldwide energy production.

Waste outputs

SU-2: Generation IV systems will minimize and manage their nuclear waste and notably reduce the long term stewardship burden in the future, thereby improving protection for public health and the environment.

Nonproliferation

SU-3: Generation IV nuclear energy systems including fuel cycles will increase the assurance that they are a very unattractive and least desirable route for diversion or theft of weapons-usable materials.

Safety & Reliability

Excellence

SR-1: Generation IV nuclear energy systems operations will excel in safety and reliability.

Core damage

SR-2: Generation IV nuclear energy systems will have a very low likelihood and degree of reactor core damage.

Emergency response

SR-3: Generation IV nuclear energy systems will eliminate the need for offsite emergency response.

Economics

Life cycle cost

EC-1: Generation IV nuclear energy systems will have a clear life-cycle cost advantage over other energy sources.

Risk to capital

EC-2: Generation IV nuclear energy systems will have a level of financial risk comparable to other energy projects.

Full Technology Goals document (8 pages) is available at: gen-iv.ne.doe.gov/pdf/finalgenivgoals_may01.pdf

System Concepts

Reactor System

- W1 Integral Primary System Reactors**
- W2 Simplified Boiling Water Reactors**
- W3 CANDU Next Generation**
- W4 Supercritical Water Reactors – Thermal Spectrum**
- W5 Supercritical Water Reactors – Fast Spectrum**
- W6 High Conversion Boiling Water Reactors**

- G1 Pebble Bed Modular Reactors**
- G2 Prismatic Modular Reactors**
- G3 Very High Temperature Reactors**
- G4 Generic High Temperature Gas Reactors – Closed Cycle**
- G5 Gas Fast Reactor**

- L1 Sodium cooled, MOX fuel, advanced aqueous process**
- L2 Sodium cooled, metal fuel, pyroprocess**
- L3 Large Pb/Pb-Bi cooled, Russian design**
- L4 Medium Pb/Pb-Bi cooled, US design**
- L5 Small Pb/Pb-Bi cooled**

- N1 Liquid Core (Molten Salt) Reactors**
- N2 Vapor Core Reactors**
- N3 Molten Salt Cooled Prismatic Fuel Reactor**

Fuel Cycle

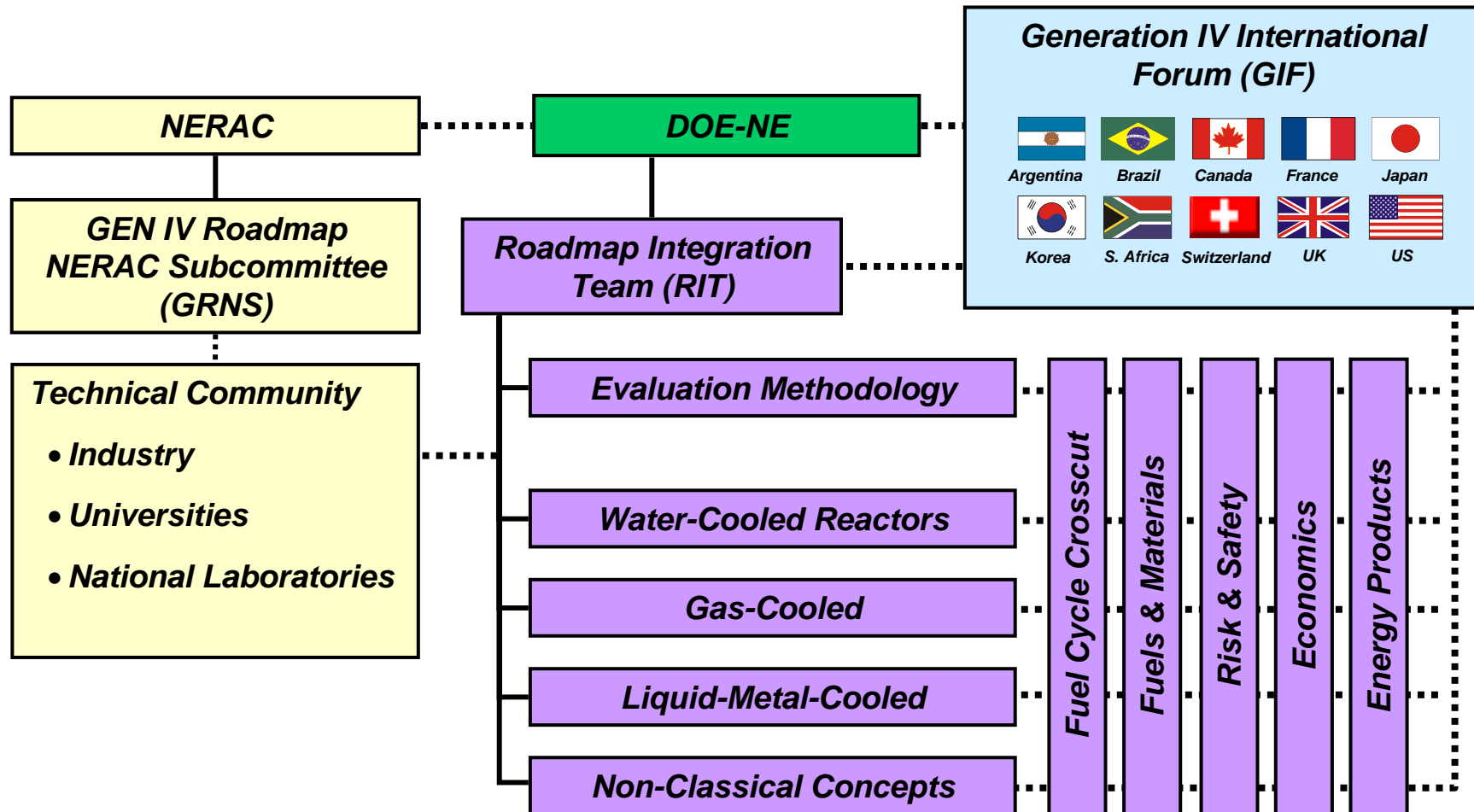
- LEU Once-through**
- LEU Once-through**
- DUPIC – partial fissile recycle**
- LEU Once-through**
- Full actinide recycle**
- Full actinide recycle**

- LEU Once-through**
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- Full actinide recycle (U,Th)**
- Full actinide recycle**

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- Full actinide recycle**

- Full actinide recycle (U,Th)**
- Full actinide recycle**
- LEU Once-through**

Organizational of the Roadmap



Evaluation Methodology Group (EMG)

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University of California - Berkeley

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Argonne National Laboratory

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International Atomic Energy Agency

Electricite de France

Framatome

Evaluation Method Philosophy

- ***Evaluate the potential for the systems to advance toward the Generation IV goals***
- ***Treat all Generation IV goals equally***
- ***Strive for comprehensive evaluations, but accept qualitative judgement***
- ***Allow for systems with different levels of maturity***
- ***Do not discriminate against less well developed systems***

Continued development of the evaluation methodology in the future is important to measure and understand R&D progress

Criteria and Metrics Overview

- **Create criteria that:**
 - **Reflect the breadth of the Generation IV Goals**
 - **Can indicate significant progress toward Goals**
 - **Will discriminate on system potential**
- **Create metrics that:**
 - **Are quantitative where possible**
 - **Contribute to future key information:**
 - **Safety analysis**
 - **Environmental impact**
 - **Business case**

The criteria are only a sampling of all that are possible

Rollup of Criteria, Goals and Goal Areas

3 Goal Areas

Sustainability

Safety and Reliability

Economics

8 Goals

SU-1 Fuel Utilization
SU-2 Waste Minimization
SU-3 Nonproliferation and
Physical Protection

SR-1 Operational Safety & Reliability
SR-2 Core Damage
SR-3 Offsite Emergency Response

EC-1 Life Cycle Cost
EC-2 Risk to Capital

24 Criteria

Fuel utilization

Waste mass
Volume

Heat load
Radiotoxicity
Environmental impact

Separated materials
Spent fuel characteristics
Passive sabotage resistance

Reliability
Worker – routine exposures
Worker – accidents

Reliable reactivity control
Reliable heat removal
Dominant phenomena certainty
Long fuel thermal response time
Integral experiments scalability

Source term
Mechanisms for energy release
Long system time constants
Long and effective holdup

Overnight construction cost
Operational costs
Construction duration

Overnight construction cost
Construction duration

Criteria and Metrics – Qualitative Example

Goal SR-1: Reliability and operational excellence

Criterion 12: Generation IV nuclear energy systems will not expose workers or the public to significant accident hazard, involving radiation, hazardous materials, or severe physical conditions. (weight: 20%)

Guidance and Discussion:

Look broadly for unique radiation, chemical, toxic, and physical hazards, during handling, transport and all other phases of operations. Evaluators must be alert to unusual potential for accidental exposure to radiation.

Final screening metric scale for Criterion 12 (based on ALWR reference)

<i>Worse than reference</i>	<i>Similar to reference</i>	<i>Better than reference</i>
<i>Significantly greater risk of accidental personnel exposure compared to Generation III</i>	<i>Risk of accidental personnel exposure about the same as Generation III</i>	<i>Significant reduction of risk of accidental personnel exposure compared to Generation III</i>

Criteria and Metrics – Quantitative Example

Goal SU-2: Waste Minimization

**Criterion 4: Generation IV systems will offer minimization of long-term heat output compared to the ALWR once-through reference system.
(weight: 30%)**

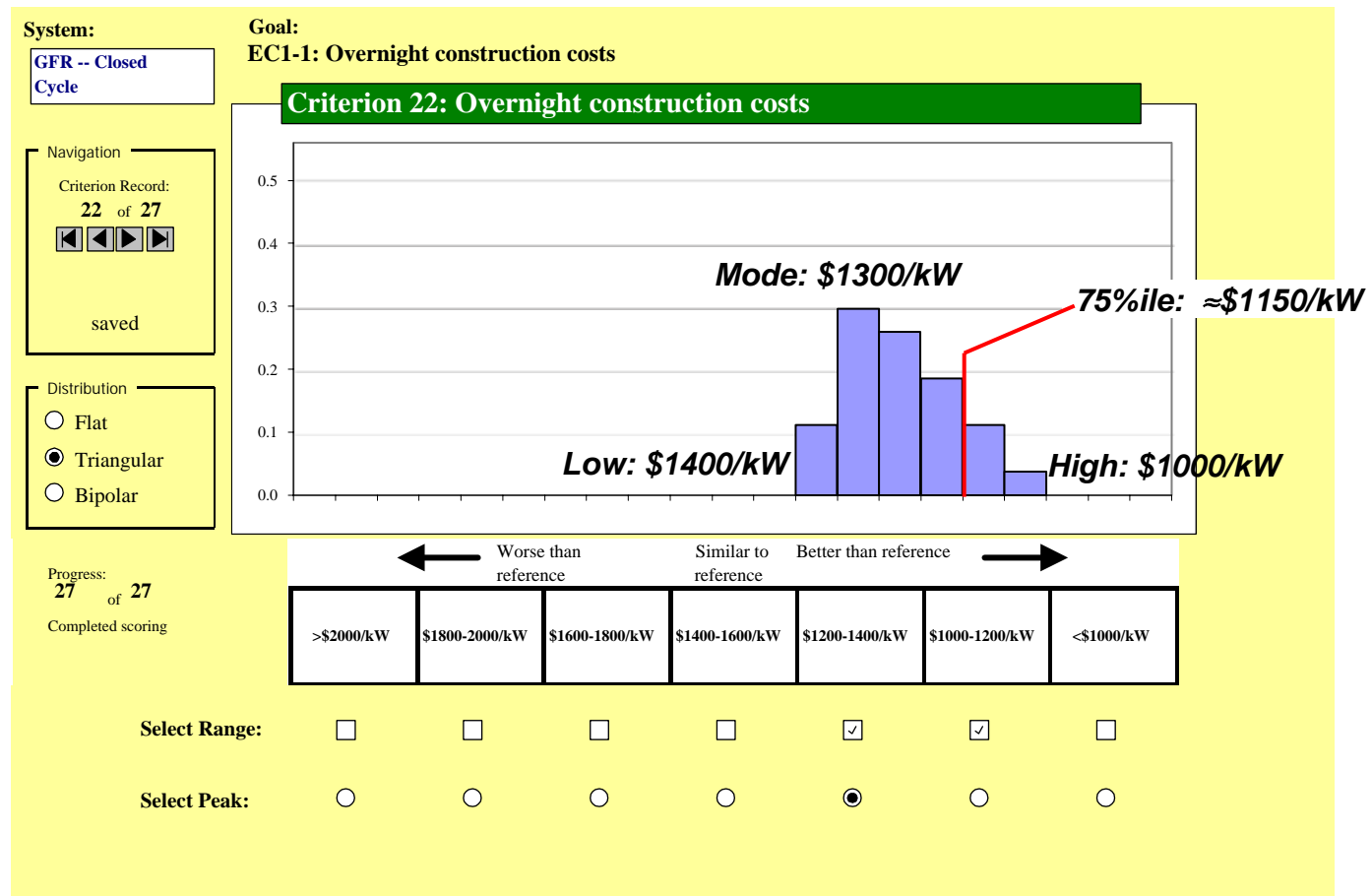
Guidance and Discussion:

Specific heat output in KW/GWyr in HLW/SNF sent to final disposal is compared to reference once-through fuel cycle. The actual calculation is performed with common assumptions, interpretations and a formula provided by the FCCG.

Final screening metric scale for Criterion 4 (based on ALWR reference)

<i>Much worse than reference</i>	<i>Worse than reference</i>	<i>Slightly worse than reference</i>	<i>Similar to reference</i>	<i>Slightly better than reference</i>	<i>Better than reference</i>	<i>Much better than reference</i>
>10 kW/GWeYr	5-10 kW/GWeYr	3-5 kW/GWeYr	1-3 kW/GWeYr	0.5-1 kW/GWeYr	0.1-0.5 kW/GWeYr	<0.1 kW/GWeYr

Criteria Scoring Example



Beyond Technology Goals: Missions

- ***The purpose of 'Missions' is to assure that the selected Generation IV concepts will adequately address a variety of important future needs, especially those for alternative energy products and fuel cycles***
- ***Four major missions have been proposed:***
 - ***Large Grid Electricity Producer***
 - ***Small Grid Electricity Producer***
 - ***Hydrogen/High Temperature Process Heat***
 - ***Actinide Management, consisting of both waste burndown and fissile creation***

Other Important Considerations

- ***R&D Costs***
- ***R&D Risks***
- ***Expected length of time for RD&D to deployment***
- ***R&D interdependencies between systems (R&D pathways)***
- ***National policies and priorities***
- ***Public confidence***

Observations on Methodology

- ***Technology goals have been a very useful focus for the criteria***
- ***Criteria and metrics take considerable time to develop as a set***
- ***Criteria frequently have interdependencies***
- ***Weighting of criteria was eventually adopted***
- ***Weighting of goals not explicit, but arises individually for countries***

Observations on Evaluations

- ***Consistency was an important issue between working groups***
 - ***Most inconsistencies were due to ambiguities in the interpretation of the criteria by the groups, and less due to advocacy***
- ***‘Rollup’ of evaluations is:***
 - ***Avoided entirely at the ‘criteria’ level, but yields too many variables (24) to easily grasp***
 - ***Good at the ‘goal’ level, but the number of variables (8) is still a bit cumbersome***
 - ***Acceptable at the ‘goal area’ level, being much easier to grasp 3 scores together, but there is noticeable loss of detailed understanding and issues***
 - ***Unacceptable at a ‘composite’ level, i.e., when reduced to a single score***